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SD TECHNICAL REPORT 61-738

**THE ELECTROCARDIOGRAM AND VECTORCARDIOGRAM  
OF NORMAL MACACA MULATTA IN DORSAL-SUPINE,  
RIGHT-LATERAL, LEFT-LATERAL, AND SITTING POSITIONS**

*F. R. ROBINSON, D.V.M.*

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**BIOMEDICAL LABORATORY  
AEROSPACE MEDICAL RESEARCH LABORATORIES**

**DECEMBER 1961**

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**AERONAUTICAL SYSTEMS DIVISION  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO**

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R. L. HAMLIN, D.V.M.*

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*DECEMBER 1961*

PROJECT No. 7231  
TASK No. 723101

AERONAUTICAL SYSTEMS DIVISION  
AIR FORCE SYSTEMS COMMAND  
UNITED STATES AIR FORCE  
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

## FOREWORD

This report was prepared in support of Project No. 7231, "Biomechanics of Aerospace Operations," Task No. 723101, "Effects of Vibration and Impact," administered by the Bioacoustics Branch, Biomedical Laboratory of the Aerospace Medical Research Laboratories, Aeronautical Systems Division. This work was accomplished in the Vibration and Impact Section of the Bioacoustics Branch, and the Veterinary Medical Section of the Research Support Branch, Aerospace Medical Research Laboratories, during the period of May to July 1961.

The Rules for Animal Care established by the American Medical Association were followed in all animal experimentation.

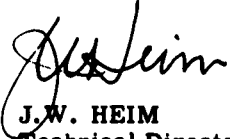
Dr. Hamlin was the veterinary consultant on cardiology of laboratory animals for the report and analyzed the experimental data. His assistance in the preparation of this report is greatly appreciated by the Aerospace Medical Research Laboratories.

The authors wish to thank G.C. Fisher, D.V.M., and D.F. Dixon, Jr., D.V.M., of the Veterinary Medical Section, Research Support Branch, Aerospace Medical Research Laboratories for their assistance.

ABSTRACT

Electrocardiograms and vectorcardiograms of 11 normal monkeys placed in dorsal-supine, right-lateral, left-lateral, and sitting positions were analyzed and results presented. This information is of immediate importance in determining electrocardiographic and vectorcardiographic changes that may be induced in monkeys by lateral impact. Leads taken were I, II, III, aVR, aVL, aVF,  $MV_1$ ,  $MV_2$ , and  $MV_3$ . Parameters analyzed from the electrocardiogram lead II included: rhythm, rate, PR interval, P wave duration, PQ segment duration, and QRS duration. The mean P vector projection in the frontal plane was also calculated. Amplitudes of the component deflections in leads I, aVF, and  $MV_1$  were determined. Vectorcardiograms were analyzed for: direction of • inscription, ratio of length to width, and the mean axis of the QRS vector projected on the three planes for each body posture. This report will serve as a base line for analysis for electrocardiographic or vectorcardiographic data analyzed in experiments on monkeys placed in any of the four positions.

PUBLICATION REVIEW



J.W. HEIM  
Technical Director  
Biomedical Laboratory

THE ELECTROCARDIOGRAM AND VECTORCARDIOGRAM  
OF NORMAL MACACA MULATTA IN DORSAL-SUPINE,  
RIGHT-LATERAL, LEFT-LATERAL, AND SITTING POSITIONS

INTRODUCTION

The monkey (*Macaca mulatta*) because of its similarities to man (refs. 1, 2) is often used in biological experimentation. Frequently, the electrocardiogram is monitored as a parameter of physiological alteration in the subject. Since little literature (refs. 3, 4, 5, 6, 7) is available on the electrocardiogram of normal monkeys placed in standard experimental positions (left- and right-lateral and sitting), this study was designed to elucidate normal electrocardiographic and vectorcardiographic values for monkeys in these most frequently used postures as well as in the dorsal supine position. These baselines will be used in the immediate future to detect electrocardiographic and vectorcardiographic changes that may be induced in monkeys involved in lateral impact studies. These animals will be subjected to high g forces in a position which may make the heart vulnerable to trauma. Our study methods were similar to those reported in the comprehensive report by Atta and Vanace (ref. 6) on normal, unanesthetized monkeys lying in the dorsal-supine position.

Materials and Methods

Five male and six female *Macaca mulatta* monkeys ranging in age from 3 to 6 years and in weight from 3 kg to 14 kg (mean 6.4 kg) were used in this study. They were all clinically healthy specimens maintained in the primate colony at Wright-Patterson Air Force Base, Ohio.

The monkeys were anesthetized intravenously with sodium pentobarbital, 30 mg per kilogram body weight. The hair was clipped from the limbs and thorax, the exposed areas were thoroughly rubbed with electrode jelly, and the standard electrocardiographic lead plates were then applied. A rubber strap was placed around the thorax at the level where the precordial leads were to be taken to assure constant positioning of thoracic leads. These leads were named and located approximately in accordance with the method of Atta and Vanace (ref. 6):  $MV_1$ , in the right fourth intercostal space, 2 cm from the sternal border;  $MV_2$ , on the left precordium symmetrical with  $MV_1$ ; and  $MV_3$ , left midaxillary line at the fifth intercostal space. In addition, an electrode was placed over the dorsal spinous process of the seventh thoracic vertebra, from which the back-point potentials were recorded for the Wilson equilateral tetrahedral vectorcardiograph reference system (ref. 8). Figure 1 shows frontal and sagittal views with electrode positions marked.

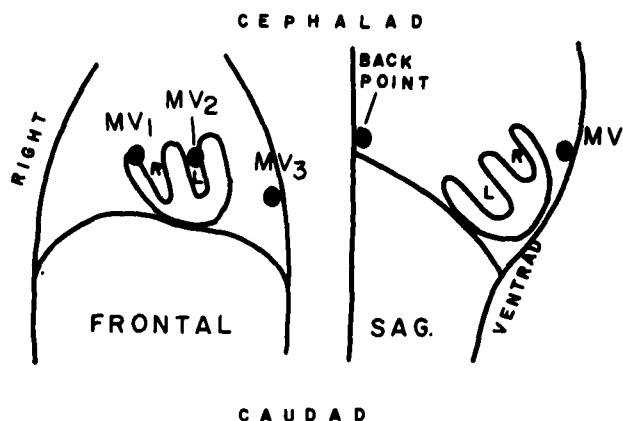


Figure 1. Schematic frontal and sagittal views of the monkey.

The heart chambers are labeled R for right ventricle and L for left ventricle. Electrode placements are labeled according to the description in the text.

Complete series of records were taken with the monkey in the dorsal-supine, right-lateral, and left-lateral recumbency, and in the sitting position. Straps attached to the ceiling were placed under the monkey's arms to raise him to a sitting position. We moved the monkey with care to avoid altering the electrode plates and to avoid wrinkling or stretching the loose skin subjacent to the electrodes so that the spatial relationship between the electrode point and the heart would not be altered. Within limits of the techniques described, the only variable between the four body postures was the position of the heart within the thorax.

Electrocardiograms were recorded on a Sanborn Twinbeam at paper speeds of 75 mm per second and a standardization of 10 mm deflection per millivolt input. The leads taken were I, II, III, aVR, aVL, aVF, MV<sub>1</sub>, MV<sub>2</sub>, and MV<sub>3</sub>. Vectorcardiograms were taken using the Sanborn Vectorcardiograph and by photographing the oscilloscope screen with a Dumont Polaroid Land camera. Time interruptions were present in the trace every 2.5 milliseconds, and the trace was shaped to give direction of inscription. The Wilson equilateral tetrahedral reference system (ref. 8) was used, with the back point being taken, as previously described, from the dorsal spinous process of the seventh thoracic vertebra. The sagittal loop is taken as if viewing the animal from its right side, according to the nomenclature of Helm (ref. 9).

General parameters analyzed from electrocardiogram lead II included: rhythm, rate, PR interval, P wave duration, PQ segment duration, QRS duration. The mean P vector projection in the frontal plane was calculated from bipolar and augmented unipolar limb leads. Amplitudes of the component deflections in leads I, aVF, and MV<sub>1</sub> were determined. The reason for excluding the remaining leads is explained in the discussion. The ratios of the magnitude of a deflection to the magnitude of each other deflection in a given QRS complex were determined, from this relative magnitudes of forces projected on the three body axes were determined. Thus, if lead aVF had a 12 mm R wave and a 4 mm S wave, the R wave was three times the magnitude of the S wave and the projection of the forces on the Y axis of the body was three times greater in the caudad direction than in the cephalad direction. The three body axes referred to in this paper are summarized below in Table I.

The vectorcardiograms were analyzed for: direction of inscription, ratio of length to width, and mean axis of the QRS vector projected on the three planes for each body posture. The mean axis was approximated by constructing a line from the origin of the loop that extended to bisect the area of the loop.



TABLE I  
RATIOS OF AMPLITUDES OF DEFLECTIONS ALONG BODY AXES

<u>Lead</u>	<u>Deflection</u>	<u>Dorsal supine</u>	<u>Right lateral</u>	<u>Left lateral</u>	<u>Sitting</u>
I	Q (initial dextrad)	1.00	1.00	1.00	1.00
	R (sinistrad)	8.66	4.67	10.66	2.88
	S (terminal dextrad)	-	-	2.33	-
aVF	Q (initial cephalad)	1.00	1.36	4.25	1.00
	R (caudad)	13.61	9.00	35.00	11.09
	S (terminal cephalad)	2.08	1.00	1.00	1.45
MV <sub>1</sub>	Q	-	-	-	-
	R (ventrad)	1.00	1.00	1.00	1.00
	S (dorsad)	2.12	1.47	1.90	2.96
		<u>Direction of force</u>	<u>Body axis</u>		
		dextral-sinistral	X		
		cephalico-caudal	Y		
		dorso-ventral	Z		

#### General Results

Table II summarizes the general findings of the 11 monkeys studied. All animals had normal sinus rhythm. The average heart rate was 215 beats per minute, ranging from 270 to 160 beats per minute.

TABLE II  
GENERAL DATA

	<u>Mean</u>	<u>Maximum</u>	<u>Minimum</u>
1. Rhythm	sinus		
2. Rate	215 beats/minute	270	160
3. P vector, Frontal plane	75 degrees	85	65
4. P wave duration	0.047 seconds	0.060	0.030
5. PR interval	0.089 seconds	0.100	0.075
6. PQ segment	0.042 seconds	0.060	0.030
7. QRS duration	0.045 seconds	0.055	0.035

Averaging data from all animals in all postures, the P vector was directed in the frontal plane at an average of 75 degrees, ranging from 85 to 65 degrees. The P wave had an average duration of 0.047 seconds, ranging from 0.060 to 0.030 seconds. The PR interval had an average duration of 0.089 seconds, ranging from 0.100 to 0.075 seconds. The average duration of the PQ segment was 0.042, ranging from 0.060 to 0.030 seconds. The average duration of the QRS complex was 0.045 seconds ranging from 0.055 to 0.035 seconds.

### Electrocardiographic Results

Representative electrocardiograms from four of the animals studied are presented in figure 2. An analysis of the amplitudes of the component deflections of the QRS complexes in leads I, aVF, and MV<sub>1</sub> taken from animals in all postures is given in table III. Table I shows the ratios of each component deflection of a given QRS complex to the other deflections of the same complex. In parentheses under the "Deflection" column are the scalar directions represented by each complex. For example, in lead aVF taken in the right-lateral posture, the ratio of peak magnitudes projected on the Y axis of the body (cephalico-caudal axis) is 1.36:9.00:1.00 for the initial cephalad, caudad, and terminal cephalad forces, respectively. In lead I taken from the animal in the sitting position, the ratio of sinistrad forces to dextrad forces is 2.88:1.00. With this analysis, one may determine what part of the total ventricular excitation complex (QRS) is generated by forces traversing the myocardium along each of the three body axes, and in which direction along the given axis.

Data from figure 2 and tables I and III have been summarized schematically in figure 3 to illustrate the "typical" QRS complex for leads I, aVF, and MV<sub>1</sub> in all four body postures.

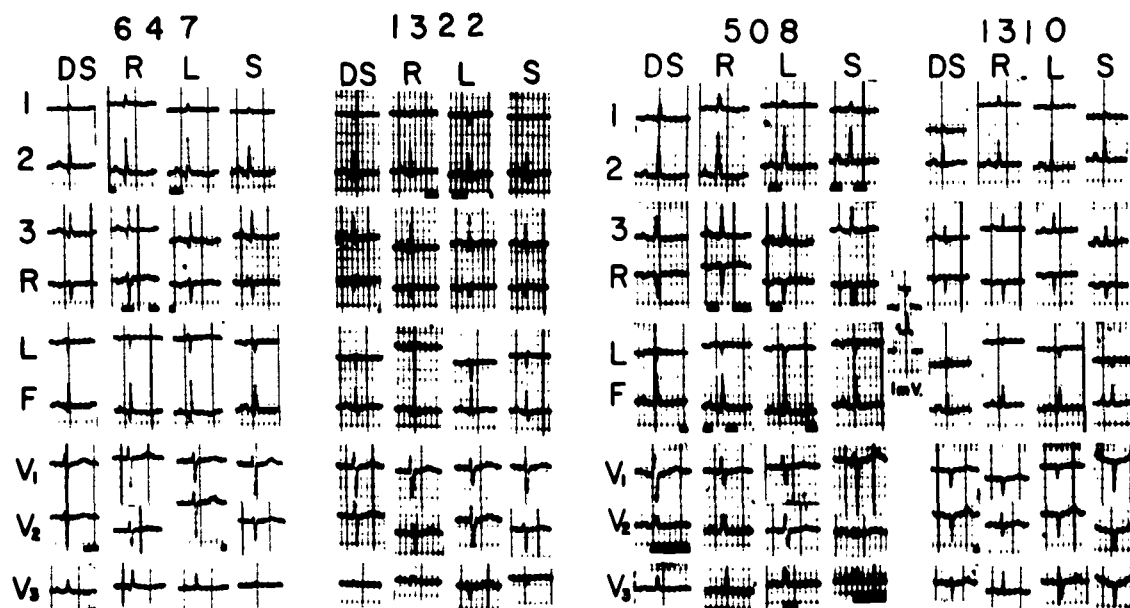


Figure 2. Electrocardiograms Recorded From the Four Animals Whose Numbers Appear at the Top of Each Series.

Body position is labeled at the top; with DS, R, L and S for dorsal-supine, right-lateral, left-lateral and sitting positions, respectively. 1, 2, and 3 stand for standard limb leads I, II, and III. R, L, and F stand for augmented unipolar limb leads aVR, aVL, and aVF. V<sub>1</sub>, V<sub>2</sub>, and V<sub>3</sub> stand for unipolar thoracic leads MV<sub>1</sub>, MV<sub>2</sub>, and MV<sub>3</sub>. A 1mV standardization appears at the center between cases 508 and 1310. This standardization is applicable throughout.

TABLE III

## AMPLITUDE (MILLIMETERS) OF DEFLECTION BY POSTURE

Lead	Deflection	Dorsal supine	Right lateral	Left lateral	Sitting
I	Q	0.45 (1.5, 0x3)	1.20 (4.5, 0x2)	0.3 (2.0, 0x4)	0.8 (5.0, 0.1)
	R	3.90 (8.0, 1)	5.60 (8.5, 0.5)	3.2 (5.5, 2.0)	2.3 (3.0, 0.1)
	S	0.20 (2.0, 0x10)	0.00 (0, 0)	0.7 (4.0, 0x8)	0.0 (0.0, 0.0)
aVF	Q	0.72 (2.5, 0.1)	1.90 (4.5, 0x1)	1.7 (4.0, 0x1)	1.1 (3.0, 0.2)
	R	9.80 (16.0, 6.0)	12.60 (21.0, 8)	14.0 (22.0, 6.0)	12.2 (19.0, 6.5)
	S	1.50 (1.5, 0x4)	1.40 (5.0, 0x7)	0.4 (2.0, 0x8)	1.6 (4.0, 0x6)
V <sub>1</sub>	Q	0 (0, 0)	0.10 (0.2, 0x4)	0.0 (0.0, 0.0)	0.0 (0.0, 0.0)
	R	5.9 (11.0, 0.5)	6.80 (9.0, 1.0)	5.0 (7.0, 4.5)	4.5 (6.0, 0.2)
	S	12.5 (16, 7.5)	10.00 (15.5, 4.0)	9.5 (13.0, 6.0)	13.3 (17.0, 1.0)

Values in millimeters, with 10 mm = 1 mV.

Mean value with range in parentheses.

When there is no deflection in a given lead, the number (0) is inserted, with the number of cases having no deflection following an X sign.

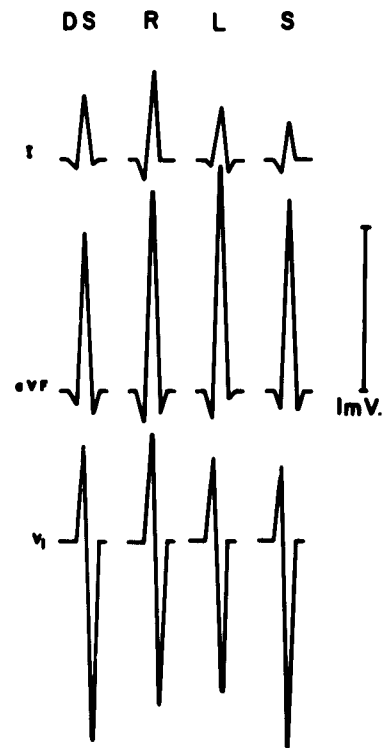


Figure 3. Schematic Representation of the QRS Complex  
"Typical" for All Monkeys in All Postures.

V<sub>1</sub> stands for MV<sub>1</sub>. Complexes are approximately to scale,  
with 1 mV standardization to the right.

Lead I in all body postures showed the lowest magnitude deflections. In the dorsal-supine posture the configuration was typically of the qR pattern, with the R wave almost nine times the amplitude of the q wave. In three monkeys the q wave was absent. In one monkey a qRs pattern was seen with the s wave being only one half the amplitude of the small q wave.

In lead I from the right-lateral posture, an s wave was never recorded, and the pattern was typical of the qR variety, with the R wave being slightly over four and one-half times the magnitude of the q wave. In this posture, the q wave was absent in two individuals.

In left-lateral posture, a great variety of configurations was observed. A small q wave was seen in seven animals, the R wave was always present, but frequently splintered with four peaks, and the s wave was seen in only three monkeys.

In the sitting position, an s wave was never seen. A q wave was seen in all monkeys but one was approximately one-third the magnitude of the R wave.

Lead aVF in the dorsal-supine posture was composed of a qRs pattern in all cases, but four in which the s wave was absent. The R wave was generally over 13 times the magnitude of the q wave. When present, the s wave was usually two times the magnitude of the q wave.

In the right-lateral posture lead aVF was composed of a q wave in all but one monkey, an R wave in all cases, and an s wave in four out of 11 monkeys. When both were present together, the q wave was slightly deeper than the s wave; but both were approximately one-ninth the magnitude of the R wave.

In the left-lateral posture, a q wave was present in all but one animal, an s wave was present in only three monkeys, and an R wave in all animals. When present together, the q wave was approximately four times greater in magnitude than the s wave; but the R wave was 35 times the magnitude of the s wave or eight times the magnitude of the q wave.

In the sitting position, a qR configuration was seen in all monkeys with an s wave in five monkeys. When both q and s waves were present, the s wave was one and one-half the magnitude of the q. The R wave was approximately 11 times the magnitude of either the q or s wave.

In lead  $MV_1$  for all monkeys in all postures, an rS configuration was observed, with the S wave from one and one-half to three times the magnitude of the r wave.

#### Vectorcardiographic Results

Figure 4 shows frontal, sagittal, and horizontal plane vectorcardiograms of the same four monkeys whose electrocardiograms were shown previously. Figure 5 shows the schematic summary of the mean QRS vector orientation in all three planes and in the four body postures. Table IV shows the orientation of the mean QRS vector with one standard deviation for three planes and all body postures in this study. Table V shows the direction with which each loop was inscribed. Table VI shows the length:width ratio for the loops.

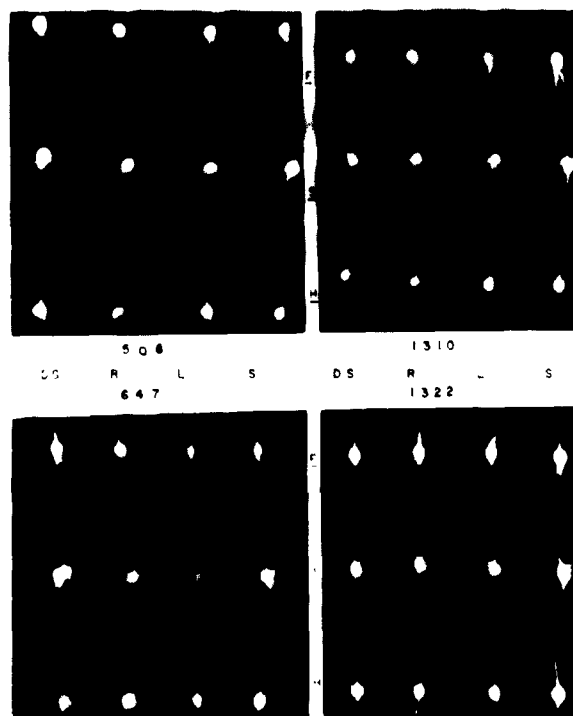


Figure 4. Frontal, Sagittal, and Horizontal Plane Vectorcardiograms Taken From the Same Four Animals As In Figure 2.

Body positions are located on the horizontal separation between cases. Planes are designated F for frontal, S for sagittal, and H for horizontal, and appear on the vertical separation between cases.

TABLE IV

MEAN QRS VECTOR

	Mean	S. D.	Maximum	Minimum
<b>Frontal Loop</b>				
Dorsal supine	69.3	28	91	-5
Right lateral	68.5	16	97	38
Left lateral	82.8	14	102	50
Sitting	81.7	6	91	40
Mean of Means	75.6			
<b>Sagittal Loop</b>				
Dorsal supine	81.3	37	113	10
Right lateral	94.0	24	112	75
Left lateral	99.3	22	112	94
Sitting	106.8	25	130	96
Mean of Means	95.4			
<b>Horizontal Loop</b>				
Dorsal supine	-27.3	33	55	-125
Right lateral	-29.0	31	52	-140
Left lateral	-60.8	46	3	-160
Sitting	-61.7	31	-15	-110
Mean of Means	-44.7			

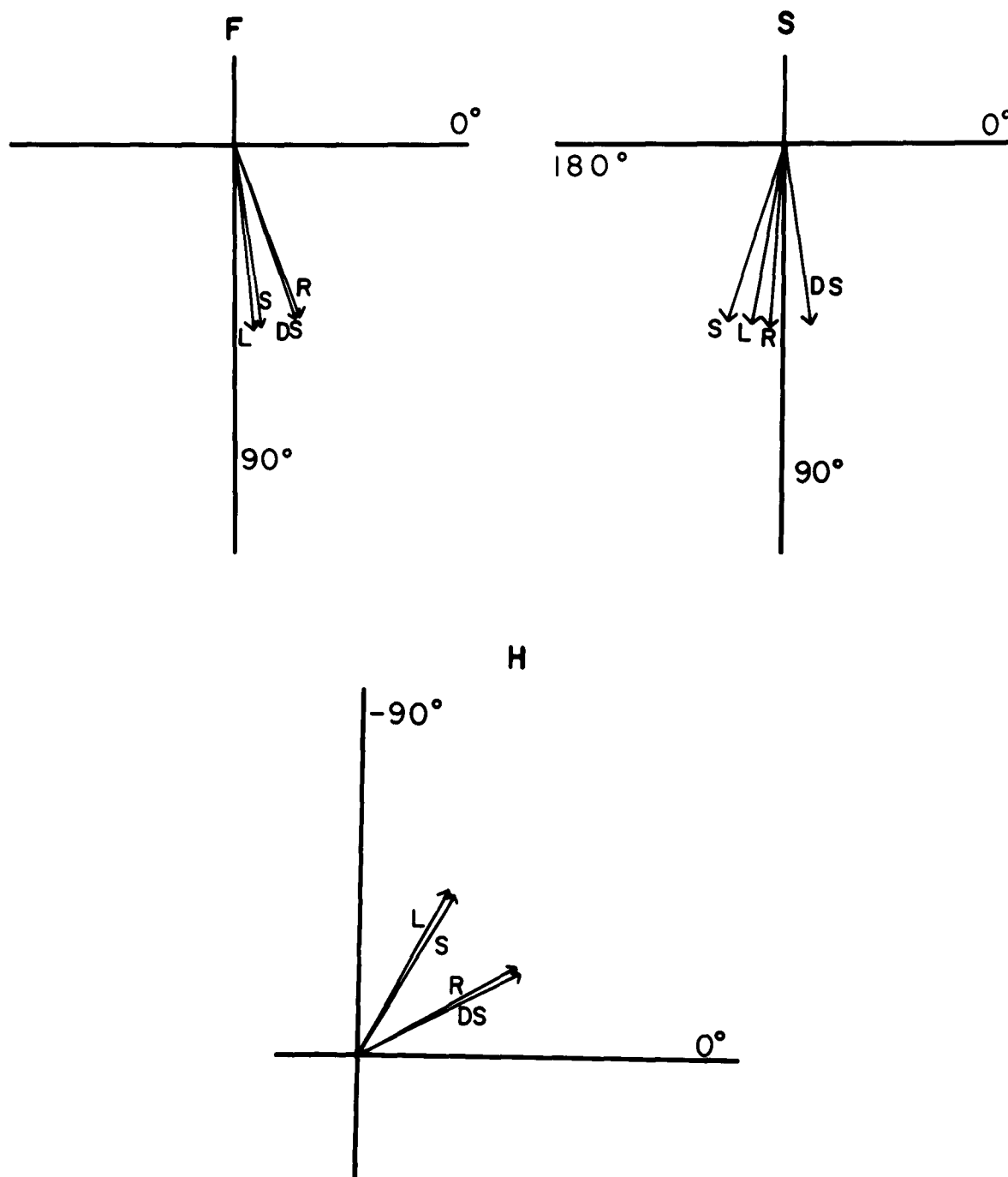


Figure 5. Mean Axes of the QRS Forces in the Frontal (F), Sagittal (S), and Horizontal (H) Planes

The position of the body is designated by DS for dorsal supine, R for right lateral, L for left lateral and S for sitting position.

TABLE V

NUMBER OF QRS LOOPS INSCRIBED WITH CLOCKWISE (C),  
COUNTERCLOCKWISE (CC), OR FIGURE  
EIGHT (8) ROTATION

	<u>Dorsal supine</u>		<u>Right lateral</u>		<u>Left lateral</u>		<u>Sitting</u>	
Frontal	C	2	C	1	C	4	C	1
	CC	6	CC	8	CC	5	CC	8
	8	3	8	2	8	2	8	2
Sagittal	C	9	C	11	C	11	C	11
	CC	0	CC	0	CC	0	CC	0
	8	2	8	0	8	0	8	0
Horizontal	C	1	C	1	C	1	C	1
	CC	9	CC	9	CC	7	CC	6
	8	1	8	1	8	3	8	4

TABLE VI

QRS LOOP LENGTH:WIDTH

	<u>Mean</u>	<u>SD</u>	<u>Maximum</u>	<u>Minimum</u>
Frontal Loop				
Dorsal supine	7.5	4.6	18.0	3.0
Right lateral	7.1	4.5	14.0	3.0
Left lateral	12.5	9.9	32.0	3.0
Sitting	16.1	12.0	40.0	4.5
Mean of Means	10.8			
Sagittal Loop				
Dorsal supine	6.3	7.3	13.5	2.0
Right lateral	2.5	1.2	4.5	1.5
Left lateral	2.6	0.8	4.2	2.0
Sitting	3.3	1.5	5.3	1.1
Mean of Means	3.7			
Horizontal Loop				
Dorsal supine	4.4	2.5	6.2	1.3
Right lateral	5.3	4.0	14.0	1.4
Left lateral	6.9	2.8	12.0	3.0
Sitting	9.6	7.3	20.0	3.0
Mean of Means	6.6			

### Frontal Plane QRS Loop

The mean axes of the QRS loops projected on the frontal plane were 69.3, 68.5, 82.8, and 81.7 degrees for the dorsal-supine, right-lateral, left-lateral, and sitting postures, respectively. The mean of the four mean values was 75.6 degrees. The ranges for mean values were wide, with the exception of that for the sitting position, which had a standard deviation of only 6 degrees.

For all postures, the loops were inscribed for the most part with counterclockwise rotation; however, because of the narrowness of the loops (a mean length:width ratio of 7.5, 7.1, 12.5, and 16.1 for the dorsal-supine, right-lateral, left-lateral, and sitting positions, respectively) the direction of inscription often became a figure eight or, at times, clockwise.

The loops had three general components:

1. Initial cephalad and slightly dextrad forces of short duration and low magnitude
2. Caudad and slightly sinistrad forces of long duration and large magnitude
3. Terminal cephalad and slightly dextrad forces of short duration and low magnitude.

The reader should note that the QRS loop "opened up" in the dorsal-supine and right-lateral postures, having a length:width ratio of nearly one-half that for the sitting and left-lateral positions.

### Sagittal Plane QRS Loop

The mean axes of the QRS loops projected on the sagittal plane were 81.3, 94.0, 99.3, and 106.8 degrees for the dorsal-supine, right-lateral, left-lateral, and sitting postures, respectively. The mean of the four mean values was 95.4 degrees. The ranges for the mean values were wide for all postures.

All sagittal plane QRS loops were inscribed with clockwise rotation. The loops in this plane had the length:width ratio closest to unity (the most "opened up" loops); with length:width ratios of 6.3, 2.5, 2.6, and 3.3 for the dorsal-supine, right-lateral, left-lateral, and sitting positions, respectively. The reader should note that the loop in this plane became narrow in the dorsal-supine position.

The loops for the most part were composed of three component groups of forces:

1. Initial cephalad but predominantly ventrad forces of intermediate magnitude and duration
2. Caudad and slightly either ventrad or dorsad forces of long duration and great magnitude
3. Terminal cephalad and dorsad forces of short duration and low magnitude.

### Horizontal Plane QRS Loop

The mean axes of the QRS loops projected on the horizontal plane were -27.3, -29.0, -60.8, and -61.7 degrees for the dorsal-supine, right-lateral, left-lateral, and sitting postures, respectively. The mean of the four means was -44.7 degrees. The ranges for these values were the greatest varying from -160 degrees to 55 degrees.



Most of the horizontal plane projections were inscribed with counterclockwise rotation; however, in each posture, one loop was inscribed with clockwise rotation and one with a figure eight in the dorsal-supine and right-lateral position, three with a figure eight in the left lateral and four in the sitting position.

The length:width ratios were 4.4, 5.3, 6.9, and 9.6 for the dorsal-supine, right-lateral, left-lateral, and sitting positions, respectively.

The projection of the spatial QRS loop on the horizontal plane had only two major groups of forces:

1. Initial ventrad and slightly dextrad forces of approximately one-half both the magnitude and duration of the terminal forces
2. Terminal dorsad and sinistrad forces

#### Summary of Results

Initial forces of short duration and low magnitude are directed cephalad, dextrad, and ventrad. This probably represents excitation of the interventricular septum in a general left to right direction (refs. 10, 11). The activity is responsible for the R wave in lead  $MV_1$ , the q waves in leads aVF and lead I, and for the initial vectorcardiographic forces oriented, spatially, cephalad, dextrad, and ventrad.

Intermediate forces of long duration and high magnitude are directed predominantly caudad and slightly sinistrad and either dorsad or ventrad. These forces probably represent excitation of the ventricular freewalls in a subendocardial to epicardial direction. Because of the predominance of left ventricular mass, excitation of this structure probably generates the dominant electrical forces (refs. 10, 11). This activity is responsible for the large R wave in lead aVF, the small R wave in lead I, and occurs probably during the isoelectric period and early during the S wave in lead  $MV_1$ . It generates the vectorcardiographic forces oriented, spatially, caudad, sinistrad, and slightly either dorsad or ventrad.

Terminal forces of short duration and low magnitude are directed cephalad, dextrad, and dorsad. They probably represent excitation of the bases of the interventricular septum and of the free-walls in an apicobasilar direction. This activity is responsible for the s waves in leads aVF and I, for the S wave in lead  $MV_1$ , and for the vectorcardiographic forces oriented, spatially, cephalad, dextrad, and dorsad (refs. 10, 11).

#### Discussion

Certain exclusions from the analysis of these records should be mentioned. The ST-T complex was not described because of the extreme low magnitude of the T wave and the difficulty in determining the ST segment. The mean T vector varied, by inspection, in the frontal plane from being parallel with the axis of the mean QRS vector to being 180 degrees divergent. In the horizontal plane, the axes of the mean QRS and T vectors were more similar. The ST segment was not deviated more than 1 millimeter in any monkey.

The vectorcardiograms did not show well the initial and terminal deflections, because of their comparatively small magnitude and the great area occupied by the point of origin. To better elucidate these forces, one must use equipment similar to that employed in the laboratory of Hellerstein (ref. 12) where he is able to dissect out differentially only the QRS portion of the total vectorcardiogram. In addition, timing was difficult to determine from the QRS loops, because of the widely spaced time interruptions, a limitation of the commercially available vectorcardiograph used in this study.

Results of this study agreed in general with those of previous studies (refs. 3, 4, 5, 6, 7) reviewed by Atta and Vanace (ref. 6). The only exception was the QRS duration. The mean QRS duration of the previously cited works is 0.028 seconds, whereas that cited in this work is 0.045 seconds. Since the data in this paper was recorded at identical paper speed and with an identical electrocardiograph, one may assume that this large difference in mean values must be due either to technique of analysis of records or to the monkeys used in this study being larger (our mean weight being 6.4 kg. to Atta and Vanace's 2.3 kg).

Although all leads recorded were included in the illustrations, only leads I, aVF, and MV<sub>1</sub> were analyzed. Theoretically three properly oriented orthogonal leads, those determining the X, Y, and Z axes of the body, give the predominance of the information about the electrical activity of the heart available through body surface leads (ref. 13). One may question the validity of selecting the three leads used in this study; if one assumes, however, that the monkey has similar ventricular excitation as the dog (ref. 6) and its heart lies within its thorax similar to man's heart within his thorax, then the form of the peripheral potentials may be rationalized. Thus, if the actual form of the potentials may be extrapolated from the theoretical pathways of depolarization, one may assume that the three orthogonal leads employed may be relied upon for at least qualitative data about the process of ventricular activation.

The effect of body posture on the mean axis of the QRS forces was not analyzed. From figure 5 and table IV it becomes obvious why such a description would be impossible, since the mean axes, by posture, are included within such narrow limits, as compared with the wide ranges within which the mean axes of each plane fall. For this reason, little correlation appears possible between movement of the "electrical" and "mechanical" axes of the heart, at least in a study with so few animals.

One final point of discussion must include the variability of the peripheral body potentials from monkey to monkey in this study. Before characterization of the peripheral body potentials of normal monkeys may be made, a far greater number of monkeys must be studied. This report in conjunction with that by Atta and Vanace, however, may serve as a baseline for analysis of electrocardiographic or vectorcardiographic data analyzed in experiments on monkeys placed in any of the four postures.

### Summary

Electrocardiograms and vectorcardiograms of 11 normal monkeys placed in dorsal-supine, right-lateral, left-lateral, and sitting positions were analyzed. Initial forces were directed cephalad, dextrad, and ventrad. Intermediate forces were directed caudad, and slightly sinistrad and either dorsad or ventrad. Terminal forces were directed cephalad, dextrad, and dorsad.

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